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"Advanced Research on Exotic Nuclei for Nuclear Physics and Nuclear Astrophysics"
The Belgian Research Initiative on eXotic nuclie: BriX Annual report 2007

March 31, 2008

Partners:

Belgian partners:

- Katholieke Universiteit Leuven (K.U.Leuven)
  Instituut voor Kern- en Stralingsfysica (IKS)
- Université Libre de Bruxelles (U.L.B.)
  Physique Nucléaire Théorique et Physique Mathématique (PNTPM)
- Universiteit Gent (U.Gent)
  Theoretische fysica - Vakgroep Subatomaire en Stralingsfysica
- Studiecentrum voor Kernenergie (SCK • CEN)

EU partners:

- Grand Accélérateur National d'Ions Lourds (GANIL), France
- Gesellschaft für Schwerionenforschung (G.S.I.), Germany
- University of Köln (IKP), Germany
- Centre de Spectrométrie Nucléaire et de Spectrométrie de Masse, Orsay (CSNSM), France

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1. Research Activities

Introduction

At the start of this annual report we briefly remind the aims and composition of the present network.

The proposed network brings together the Belgian expertise on theoretical and experimental nuclear physics, nuclear astrophysics and accelerator driven systems, and will execute, in a coherent and collaborative effort, a research program focussed around radioactive ion beam research. Together with the EU partners, a carefully selected sample of atomic nuclei most of them with extreme proton to neutron ratios will be studied to bring key elements for a better understanding of the manifestation of the strong, weak and electromagnetic interaction in the nuclear medium. Key experiments on the properties of exotic nuclei through decay, moment and reactivity measurements are proposed while the beta decay of specific isotopes will serve the weak interaction studies. Theoretical studies are directed towards few-body models, mean field descriptions and shell models and their symmetries. The results will be used for nuclear-structure studies, weak interaction studies and nuclear astrophysics, as well as to investigate fundamental nuclear physics aspects of accelerator driven systems.

The focus of the program can thus be summarized in the following list of items that are planned to be studied:
- Study of light exotic nuclei: structure, decay properties and reactivity: few-nucleon correlation effects, clusters structures, halo and skin structures

- Study of medium-heavy and heavy nuclei with a closed shell configurations for protons or neutrons: effective interactions in nuclei with extreme N/Z ratio, shape coexistence

- Study of nuclei along the N=Z line: pairing correlations, deformation driving phenomena, exotic decay modes, T=1 and T=0 interactions, weak interactions

- Set-up effective interactions that will allow unrestricted shell-model studies for the largest possible model spaces in order to explore better the extremes of the nuclear shell model and an effective interaction, in the form of an energy density functional, in conjunction with a beyond mean-field method.

- Study of the nuclear physics aspects of reactions of astrophysics interest

- Study of rare actinides: nuclear structure, neutron-capture, accelerator driven systems

The Belgian partners of the network are experimental groups from IKS-K.U.Leuven, U.Gent and SCK-CEN (Mol) and thoeretical groups from U.L.B. (Brussels) and U.Gent. The EU partners are GANIL (Caen, France), GSI (Darmstad, Germany), the Institute of Nuclear Physics of the University of Köln, UNI Köln (Köln, Germany) and the Centre de Spectrométrie Nucléaire et de Spectrométrie de Masse, CSNSM (Orsay, France).

Experimental campaigns and/or preparatory activities have taken place at the radioactive beam facilities of Louvain-la-Neuve (Belgium), ISOLDE-CERN (Switzerland), GANIL (France), GSI (Darmstadt) and K.V.I. (Groningen), and at the

SCK•CEN and GELINA (Belgium) and ILL (France) neutron facilities. The major theoretical efforts were closely related to the experimental work in order to stimulate mutual feedback between theory and experiment.

Based on the expertise within the network and the importance of the scientific issues, this resulted in a number of work packages (WP). The report of the research activities is ordered according to the work packages as defined in the original proposal.

Progress report according to the work packages

Objective 1:
We want to increase the selectivity of the LISOL laser ion source and to optimise the experimental conditions at the Penning trap based WITCH (ISOLDE) and SHIPTRAP (GSI) projects.

	Workpackage 1: **Preparation of radioactive ion beams**	**Partners**
1	Optimisation of the LISOL laser ion source and development of new laser ionisation schemes	K.U.Leuven
2	Optimisation of the overall experimental conditions at SHIPTRAP related to studies along the N=Z line	K.U.Leuven – GSI
3.	Feasibility study to perform spectroscopy measurements with WICH and SHIPTRAP	K.U.Leuven – GSI

1.1
A series of modifications and off-line tests have been performed to upgrade the LISOL laser ion source. The aim was to:
- reduce the delay time of the gas cell system
- increase the selectivity of the ion source
- characterize through extended gas flow simulation the performances of the cell

A new so-called shadow gas cell was constructed whereby the laser ionization volume was physically shielded from the volume in which the reaction products were stopped. This should allow us, for the first time, to use electrical fields in on-line conditions. So far all attempts to use electrical fields in on-line conditions failed while in off-line conditions the use of electrical fields was very successful. This was understood as being due to the high plasma density the shielded the electrical field and made ion and/or electron collection impossible. The shielding was realized by building a chicane structure in the gas cell. Extended gas flow simulations showed that the loss of atoms/ions due to wall collisions was manageable. The first on-line tests were successful and allowed the installation of condenser plates to create an electrical field that allowed to remove the unwanted ions. After these first on-line tests, the shadow gas cell was further modified to prepare for new on-line tests in 2008 to measure precisely the selectivity obtained on-line in a heavy ion fusion evaporation reactions as well as proton induced fission reactions.

The reduction of the delay time was investigated by extended gas flow simulations. In first instance the present gas cell used for fusion evaporation and the one for fission reactions were fully simulated. From this it was concluded that for the fission cell only a rather small fraction of the gas cell was evacuated within 500 ms (the arbitrary limit we have put for the evaluation), meaning that a large part of the cell was not effectively used for the production of the exotic ion beams. The reason for this deficiency was of course the 0.5 mm exit hole diameter and the argon buffer gas

used in our experiments. Detailed work with different gas cell configuration, however, did not reveal a substantially better solution for this inherent problem. The only, straightforward solution was to increase the exit hole diameter to 1 mm. This would reduce the losses of short lived isotopes with half lives in the 100 ms range by at least a factor of two. In order to be able to use this larger exit-hole diameter, we had to reconfigure the sextupole ion guide RF structure and the front end pumping system. A new structure was built and tested off-line. The test showed our capability to use 1 mm exit-hole diameters and on-line tests are foreseen in 2008.

Finally, it should be noted that the so-called "Laser Ion Source Trap" mode was successfully tested off-line. Hereby atoms are evacuated from the gas cell, blown into the expansion zone where an RF –trap is situated, resonantly ionized, trapped by the RF electrical fields and extracted from the RF trap before they escape as atoms. This method will allow us to eventually perform laser spectroscopic measurements as was shown off-line with the three stable isotopes from nickel where the isotope shift was measured. On-line tests are foreseen in 2008.

1.2
No activity was performed in 2007

1.3
For WITCH two possible set-ups are being considered. The first is the installation of a tape station on top of the WITCH apparatus. Simulations have shown that a narrow (few millimeter diameter) beam spot can be created on the tape when ions are expelled from the WITCH Penning ion trap and are accelerated to about 5 -10 keV. Simulations also learned that the large electrode of the retardation spectrometer can be use for this.
The second set-up is a new and compact beta spectrometer consisting of a multi-wire drift chamber for electron tracking and a semiconductor detector for the energy determination. Such a combination allows one to reject events that were (back)scattered on the energy detector, and has an efficiency that is about two orders of magnitude larger than that of the 'classical' magnetic beta spectrometers. Tests are ongoing to define the optimal operating parameters for the drift chamber and find the best-suited windows to seal the drift chamber with minimal disturbance of the beta particle trajectory.

Objective 2:
We want to model and analyse a selected set of nuclear reactions of astrophysics interest, including an experimental study of neutron-capture reactions.

	Workpackage 2: **Study of reactions of astrophysics interest**	**Partners**
1	Theoretical study of nuclear reactions of astrophysical interest: microscopic models, direct reactions and R-matrix analysis	U.L.B.
2	Theoretical and experimental study of neutron capture reactions of astrophysical interest	U.Gent – U.L.B.

2.1
- Scattering lengths
Low-energy elastic scattering can be parameterized by effective-range expansions. However, except for the scattering length in neutron scattering, its coefficients can not often be measured with accuracy. For a number of systems, a phase shift

analysis is available. We have shown that microscopic resonating-group calculations can reproduce these phase shifts very well. We then made use of the same model to derive the effective-range expansion. The first coefficients of the effective-range expansion are derived by a direct calculation at zero energy, i.e. without extrapolation, in the generator coordinate version of the resonating-group method. The parameters of the effective nucleon-nucleon interaction are adjusted on available experimental data (phase shifts or binding energies). A scattering length and an effective range consistent with existing data have been determined in this way for the α+n, ^{16}O+n, ^{14}C+n neutron scatterings, α+p, ^{16}O+p, ^{14}O+p proton scatterings, and α+ α, α+^{3}H, α+^{3}He collisions between light ions. In many cases, neutral and charged, the effective-range expansion is valid up to energies larger than 5 MeV. For α+ α, the scattering length and effective range can be derived from the properties of the 8Be ground-state resonance. These results provide a simple parameterization of elastic cross sections at low energies.

- Microscopic models

The ^{12}C(α,γ)^{16}O reaction plays a crucial role in nuclear astrophysics, but obtaining the cross section raises many difficulties, on the theoretical as well as on the experimental sides. The determination of the reaction rate at stellar temperatures≈(3x10^{8} K) requires an extrapolation of the cross section down to 300 keV. At such low energies the cross section is too small to be measured in laboratories, and all extrapolations rely on theoretical models. One of the specificities of the ^{12}C(α,γ)^{16}O is that it combines E1 and E2 multipolarities. If the E1 component seems to be well understood, the E2 part is still uncertain by a large factor. We have investigated this reaction in a microscopic cluster model involving all p-shell states of ^{12}C. This represents a significant improvement compared to previous works. This microscopic analysis has been complemented by a phenomenological R-matrix approach. We have shown that current data on capture and elastic scattering do not allow a precise determination of the rate. Consequently, we have repeated the R-matrix analysis by using the Asymptotic Normalization Constant (ANC) of the 2^{+} subthreshold state, in order to constrain the fit. By using this procedure, we end up with an E2 S-factor S_{E2} (300 keV) $\approx$ 42 keV-b, lower than currently accepted in data compilations.

- Indirect methods

The ANC method has been proved to be very efficient for capture reactions to weakly bound states. In such systems, the electromagnetic matrix elements at low incident energies are essentially given by the asymptotic behaviour of the wave functions. The energy dependence of the cross section is then provided by properties of the Coulomb functions, and its amplitude by the normalization of the bound-state wave function at large distance. This amplitude is called ANC and determines the cross section provided that the final state is weakly bound. In collaboration with N. Timofeyuk (University of Surrey), we have recently addressed the problem of charge symmetry of ANC. In many pairs of mirror systems, one of the nuclei is easier to investigate experimentally. In that case, the link between the ANCs is an important issue. This link has been established on the basis of simple assumptions, but needs to be tested by elaborated models. We have used a microscopic cluster model to investigate the charge symmetry of ANCs in α+nucleus systems. We have determined the ANC of some pairs of mirror nuclei (α+^{15}N/^{15}O, α+^{7}Be/^{7}Li, etc) and compared their ratios with the simple approximation. On the other hand, we have used this formalism to investigate the ^{26}Si(p,γ)^{27}P reaction from the experimental ANC of the ^{27}Mg mirror nucleus.

2.2

The $^{26}Al(n,\alpha)^{23}Na$ reaction cross section has been measured at the GELINA neutron spectrometer of the Institute for Reference Materials and Measurements (IRMM) in Geel up to about 100 keV, using the time-of-flight technique. A Frisch-gridded ionisation chamber with ultra pure methane as detector gas was used for the detection of the α particles. Six resonances could be observed in this energy region, whereas before only one had been identified experimentally. For four of them, resonance parameters such as resonance energy, total width, area, and spin of the state could be determined. From the obtained $^{26}Al(n,\alpha)^{23}Na$ reaction cross section data, Maxwellian averaged cross section values (MACS) for stellar temperatures up to 45 keV were calculated by numerical integration. Since neutron induced reactions are amongst the major destruction mechanisms of ^{26}Al in our Galaxy, these new MACS values contribute to a better understanding of the observed ^{26}Al abundance.

Objective 3:
We want to investigate the properties of key states in light exotic nuclei, compare them with the theoretical models developed within the collaboration, and understand the possible influence on the reaction mechanism at energies around the Coulomb barrier.

	Workpackage 3: Light exotic nuclei	**Partners**
1	Experimental investigation of the structure of light nuclei	K.U.Leuven – U.L.B. - GANIL
2	Reaction studies around the Coulomb barrier	K.U.Leuven – GANIL
3	Development and exploitation of cluster models and experimental investigation of light exotic nuclei using beta decay and reaction studies	U.L.B. – K.U.Leuven
4	Development and exploitation of break-up models for intermediate and relativistic energy reactions with light exotic nuclei	U.L.B. – GSI

3.1
The study of light exotic nuclei via their β-delayed charged particle emission has been the focus of much recent attention. Calorimetric experiments have been performed using the same Double Sided Silicon Strip Detector (DSSSD) both for the implanted ions and the emitted particles in the decay (implantation method).
Last year the main focus was on the measurement of the β-decay of ^{8}B, where the neutrino spectrum was aimed for by detecting the α-particles from the breakup of ^{8}Be populated in the β-decay of ^{8}B in order to compare it with solar neutrino experiments. For the extraction of the relevant information we will also make use of our previous measurement of the ^{8}Li decay, obtained with the same technique at TRIUMF, Canada. A consistent comparative analysis of the two spectra will provide a better understanding of the ^{8}Be 2^{+} final-state continuum, allowing us to isolate effects due to the experimental method. Since this is a precision measurement we designed a cooling system for the DSSSD in order to provide more stable conditions and a better energy resolution. The experiment was scheduled in December 2007 at the Kernfysisch Versneller Instituut (KVI) in Groningen but had to be postponed due to technical problems with the production of the primary beam. Meanwhile a complementary experiment has been performed in January 2008 at Jyväskylä (JYFL) measuring the emitted α-particles in singles or coincidence after implantation of the ^{8}B ions on a C-foil. The analysis of both experiments will be performed by researchers from Aarhus, Denmark and Leuven.
Within the same collaboration the analysis of an earlier experiment at KVI, studying states in ^{12}C, was finished last year. The interest in experimental studies of the ^{12}C

nucleus is partly due to astrophysical interest in its spectroscopic properties, which determine the triple alpha reaction rate, and partly motivated by the structure of the nucleus, which is not fully explained theoretically. We performed new experiments using β-decay of ^{12}B and ^{12}N populating states with spin and parity: 0^+, 1^+ and 2^+ in ^{12}C, measuring the full energy spectrum of the 3 emitted α-particles and calculating the respective branching ratios.
Also in 2007, analysis was further being performed on previous experiments concerning the two-neutron halo system ^{11}Li (TRIUMF, 2005). The deuteron (triton)-emission channel of the β-decay of ^{11}Li was identified by correlating the decays of ^{11}Li with those of the daughter ions. The implantation method allowed for obtaining a precise value for the branching ratios. During the same campaign the charged particle β-decay of ^{11}Be was measured by implanting the ^{11}Li ions in a 20s-20s beam on-off sequence. The emitted α-particle and corresponding ^{7}Li recoil ions, following the population of a higher lying state in ^{11}B, are detected in the DSSSD. The branching ratios of the decay of the latter state to the ground state and the 478-keV excited state of ^{7}Li are evaluated.

3.2
Alongside the β-decay studies, reaction studies using light nuclei were performed. At the end of 2006 we performed an experiment at the Cyclotron Research Centre in Louvain-la-Neuve measuring the elastic cross section of ^{6}He on a ^{238}U target at energies around the Coulomb barrier. The aim was to compare the behavior of ^{6}He with that of ^{4}He; to extract reliable Optical Model parameters, which are an important ingredient in models for the calculation of the cross sections; and to derive limits on the total cross section. At the same time, the fusion and transfer cross sections could be re-measured. The position-sensitive detectors were used here for the first time and their performance was good and reliable. The complete analysis is being performed at Leuven.
The astrophysically important 14O(α,p)17F was studied in time reverse kinematics at REX-ISOLDE, CERN. In particular, the highly efficient miniball + CD detection system was used to measure the previously undetermined inelastic proton branch of the 1^- state at 6.15 MeV in ^{18}Ne. This state dominates the reaction rate under X-ray burster conditions.

3.3
- Exactly-solvable coupled-channel models from supersymmetric quantum mechanics
We have constructed an exactly-solvable two-channel potential model, with a threshold difference between the two channels and zero angular momentum for both channels (s waves). This has been realized by applying a supersymmetric-quantum-mechanics transformation to a vanishing initial potential. All properties of the obtained potential are known analytically; in particular, the elements of its Jost matrix are rational functions of the channel wave numbers. From this Jost matrix, all bound-state and scattering-state properties of the potential can be obtained analytically. This potential was known in the literature as the Cox potential but our construction method allows both its generalization and a much simpler study of its properties. In particular, we have proved that the potential can have 0, 1 or 2 bound states, depending on the value of its parameters, as well as 0 or 1 resonance, of the Feshbach type. We have also calculated its low-energy scattering behavior.

This rather simple potential opens the way to more sophisticated coupled-channel models, which could be obtained by iteration of supersymmetric transformations and which could fit scattering data with more complicated features (larger number of bound states and resonances, larger number of channels, etc). On the long term, we

expect such models to be applicable to describe low-energy nuclear collisions and reactions. However, as a first application, we have used our potential to describe atom-atom interactions. Though the formalism of scattering theory is the same in nuclear and atomic physics, atom-atom interactions have simplifying features with respect to nucleus-nucleus interactions: there is no Coulomb potential, as atoms are neutral, and coupled s waves are physically relevant. This case is thus ideal to test our model. With our potential, we have been able to describe the magnetic Feshbach resonance phenomenon analytically. In particular, we have described successfully the interaction between a Feshbach resonance and a bound- or virtual-state close to threshold. This proves that our model, despite its simple form, is flexible enough to describe sophisticated physical contexts.

- Renormalized RGM

Microscopic cluster models are based on fundamental principles of quantum physics, such as the Pauli principle, but require in general rather heavy numerical calculations. The Resonating Group Method (RGM) for example assumes that a nucleus presents a substructure, composed of clusters. Essentially 2 and 3 cluster models have been developed. Approximations of the RGM have been proposed since many years. These approximations provide equivalent nucleus-nucleus potentials (such as α+n or α+α) but these potentials are energy dependent and cannot be used in multicluster theories without ambiguity. In collaboration with Y. Suzuki (Niigata, Japan) and Y. Fujiwara (Kyoto, Japan), we have reformulated the RGM equation in order to derive a nucleus-nucleus potential which is non local, but energy independent. We have determined α+n and α+α potentials and used them in 3-body systems: ^{6}He=α+n+n, ^{9}Be=α+α+n and ^{12}C=α+α+α The calculations have been done in parallel with two well known 3-body techniques (the hyperspherical method and the Faddeev method) in order to crosscheck the calculations. This "semi-microscopic" model has been compared to the full microscopic 3-cluster calculation, using the same nucleon-nucleon interaction.

- Ab initio calculations

Cluster models require the use of "effective" nucleon-nucleon interactions. To go beyond this approximation, and to use "realistic" forces, the cluster approximation has to be replaced by "ab initio" models. Different variants exist and are, until now, essentially applied to the spectroscopic of light nuclei (typically up to A=12). In collaboration with S. Aoyama and Y. Suzuki (Niigata, Japan), we have started ab initio calculations for reactions involving very light nuclei (d+p and d+d).

3.4

- Breakup reactions

Breakup reactions are one of the main tools for the study of exotic nuclei. In particular, Coulomb breakup is expected to provide information on spectroscopic properties of halo nuclei and on astrophysical S factors for radiative-capture reactions. The simplest studies are based on perturbation theory and especially on its first order. However the validity of the first-order approximation may be limited for extended systems such as halo nuclei and its conditions are not always satisfied in existing experiments. In recent years, we have developed more elaborate reaction models: resolution of the semi-classical time-dependent Schrödinger equation, eikonal and dynamical eikonal approximations. These methods were first applied to the ^{11}Be breakup.

The ^{8}B breakup is expected to provide information on the astrophysical S factor for the ^{7}Be(p,γ)^{8}B reaction at stellar energies. Various experiments have been performed at RIKEN, MSU and GSI with this aim. Some of these data are well reproduced by

theory but others remain poorly explained. Moreover no model did agree with all data. We have used the dynamical eikonal approximation to analyze various measurements of the Coulomb breakup of ^{8}B with a common description of ^{8}B. We obtain a good agreement with experiment for different observables measured between 40 and 80 MeV per nucleon at RIKEN and MSU. A simple ^{7}Be+p potential model description of ^{8}B seems sufficient to describe all these observables. In particular, while CDCC studies have failed to reproduce the asymmetry in parallel-momentum distributions due to E1-E2 interferences, it is well reproduced within the dynamical eikonal approximation without any scaling of the E2 contribution. The projectile-target nuclear interactions seem negligible if data are selected at forward angles. On the contrary, like in previous analyses, we observe a significant influence of higher-order effects. The accuracy of astrophysical S factors for the ^{7}Be(p, γ)^{8}B reaction at stellar energies extracted from breakup measurements therefore seems difficult to evaluate but is not as good as initially hoped.

We have also applied the dynamical eikonal approximation to a study of the ^{19}C halo nucleus described as ^{18}C+n on ^{208}Pb. A d5/2 resonance in ^{19}C is expected to influence the breakup cross section but its location is unknown. We have shown that the existing RIKEN data indicate that this resonance should be located either at very low relative energies between ^{18}C and neutron (<0.3 MeV) or beyond 1 MeV.

Breakup reactions of halo nuclei are also used as indirect techniques to infer information about the structure of these projectiles. It is usually assumed that the ratio between the theoretical estimation of the cross section with the actual measurements gives access to the Spectroscopic Factor (SF) of the dominant configuration in the projectile wave function. Alternatively, it has been suggested that, breakup reactions of loosely-bound projectiles being very peripheral, only the Asymptotic Normalisation Coefficient (ANC) can be extracted from measurements. In order to disentangle these two opposite viewpoints, we performed, in collaboration with F. M. Nunes of the National Superconducting Cyclotron Laboratory (Michigan State University, USA), an analysis of the peripherality of breakup reactions. We compared breakup calculations performed using two descriptions of the projectile that exhibit exactly identical asymptotics, but very different interiors. No difference was observed between both calculations for light and heavy target, at low and intermediate energy, for neutron- and proton-halo nuclei. This leads us to conclude that breakup reaction of loosely-bound nuclei are indeed peripheral in the sense that only the tail of the projectile wave function is probed during this process. This result strongly favours ANC techniques against SF measurements.

The traditional eikonal approximation is interesting because of its relative simplicity with respect to other elaborate models. However it suffers from a divergence problem associated with the treatment of the Coulomb interaction. In collaboration with Y. Suzuki (Niigata University, Japan), we have started a study of a correction curing this problem. This correction is devised in such a way that at large impact parameters the corrected eikonal results tend to those of first-order perturbation theory and the corresponding cross section thus converges. We have started testing this improved eikonal treatment with the more elaborate (but much more time-consuming) dynamical eikonal approximation on the ^{11}Be breakup on ^{208}Pb.

Objective 4:
We want to study medium-heavy and heavy closed shell nuclei in order to obtain key information to test and improve the predictive power of nuclear models far from stability

	Workpackage 4: **Studies of medium-heavy and heavy closed shell nuclei**	**Partners**
1	Study of the changing shell structure in neutron rich nuclei near N=20 and N=28	K.U.Leuven – U.L.B. – U.Gent – GANIL - CSNSM
2	The influence of exotic neutron-to-proton ratios on the shell structure and the onset of collectivity in the neutron-rich Z=28 region.	K.U.Leuven – U.L.B. - U.Gent – CSNSM – Köln – GANIL
3.	Intruder states in the Pb region and the microscopic origin of collectivity	K.U.Leuven – U.L.B. – U.Gent – GANIL – Köln – CSNSM – GSI
4	Proof the presence of spin-alignment in relativistic U-fission at the FRS-GSI. Investigate the changing shell structure near the doubly-magic neutron-rich ^{132}Sn via moments measurements.	KU Leuven – Köln – GSI – CSNSM

4.1
The shell structure of neutron-rich isotopes with approximately 20 or 28 neutrons is deviating from the predictions by modern shell model theories based on effective nucleon-nucleon residual interactions. To investigate this change in the shell structure, nuclear moments are ideal tools, because they can be measured in a model-independent way. Experimental moments compared to predictions from nuclear models, allow getting insight in the changing shell structure and can help to understand the origin of this change with isospin.

An experimental programme has been started and will continue in this IAP-phase, to investigate in a systematic way the nuclear moments, ground state spins and changes in mean-square radii of neutron rich isotopes in these neutron-rich 'islands of inversion' near N=20 and N=28: regions in the nuclear chart where intruder configurations are influencing, even dominating, the nuclear ground state. The Mg and Al isotopes around and beyond N=20, as well as in the Cl and K isotopes approaching and beyond N=28, provide ideal laboratories to study the effective proton-neutron interaction between the sd-shell and pf-shell orbits as a function of isospin.
The Mg isotopes are best produced at ISOLDE-CERN, where they are investigated using the collinear laser spectroscopy and β-nuclear magnetic resonance (β-NMR) methods at the COLLAPS beam line (in collaboration with University of Mainz). This programme has been started during the previous IAP phase, with several publications resulting from this work (see list of publications). The ground state spins and moments of all odd-Mg isotopes from N=9 up to N=21 have been measured and revealed interesting results. The ground state structure of the neutron-rich ^{31}Mg and ^{33}Mg isotopes (N=19,21) is found being dominated by intruder configurations. This research will continue in the next years, with the aim to measure now also the changes in mean square charge radii and get a direct proof of the static deformation of these isotopes, which is related to their intruder nature.
The Al and Cl isotopes are ideal cases to be studied by β-NMR techniques at the LISE fragment separator at GANIL. In collaboration with our IAP partners, interesting results have been obtained already on the neutron rich Al isotopes during previous

IAP phase, revealing a gradual transition of the nuclear structure from the normal sd-shell into the island of inversion. This year, we plan to measure the quadrupole moments of these isotopes, in order to be more sensitive to a possible deformation induced by the mixing with intruder configurations in the N=20,21 Al isotopes. The odd-Cl ground states from N=20 to N=28 are predicted to have a changing proton structure when filling the N=28 shell. By measuring the ground state g-factors, we will be able to probe this change, and reveal the nature of the unpaired valence nucleons which play a role in the ground state configuration. This will shed light on the evolution of proton single particle orbits as function of isospin, as well as on the possible collapse of the N=28 shell gap. A proposal was accepted at GANIL, and a first successful experiment was performed in 2007, and will be continued in 2008.
With the same motivation, we are preparing a proposal to study the ground state properties of neutron-rich K isotopes around and beyond N=28. These isotopes are ideal to be investigated by collinear laser spectroscopy, using the new ISCOOL cooler/buncher which has been recently installed at ISOLDE-CERN. With this tool, we can improve our detection sensitivity by a factor of 1000 and thus extend the measurements far beyond N=28.

A one-neutron transfer reaction on ^{30}Mg(d,p) to characterize the state in ^{31}Mg has been performed at ISOLDE with a new reaction chamber (see further). The data is under analysis.

4.2
In the neutron rich region along the Z=28 magic number (Fe, Ni, Cu), several isomeric states have been observed. The g-factors and quadrupole moments of these states can provide information about the quick onset of deformation above and below Ni, as well as on the migration of the proton fp levels with increasing neutron number. The quadrupole moment of a 9/2+ microsecond isomer in 61Fe has been investigated at GANIL in collaboration with our GANIL and CSNSM partners, revealing an increase in deformation in this intruder isomer. Longer-lived isomeric states and ground states of Cu isotopes have been investigated using collinear laser spectroscopy at ISOLDE (collaboration with Mainz, Manchester, GANIL). First experiments have been performed in 2007, and will be continued in 2008 for the more exotic isotopes using the ISCOOL cooler/buncher. We have been able to establish the ground state spin of 72Cu and we observed a clear reduction in the ground state deformation when approaching the N=40 semi-magic nucleon number.

Coulomb excitation measurements have been performed on the neutron-rich Zn and Cu isotopes. Results have been obtained up to ^{80}Zn (with a closed N=50 shell) and up to ^{73}Cu. The data have been fully analysed and published. The data on the Zn isotopic chain indicate that in order to reproduce the data with large scale shell model calculations the polarization of the Z=28 is needed while it is not needed for the N=50 neutron shell. The Coulex data the cupper isotopes show the existence of an unexpected low-lying excited state previously not observed in beta decay studies and that has a degree of collectivity. This state can not be reproduced by theoretical models and evidences shape coexistence in the Cu isotopes. Furthermore the study proved that the $5/2^-$ state previously observed in beta decay studies and whose energy has a peculiar behaviour probably due to the filling of the neutron $g_{9/2}$ shell, has indeed a single particle structure. Finally, the Coulex data on the isomers in the Cu isotopes was published evidencing the fragility of the N=40 sub-shell closure around ^{68}Ni and the analysis of Coulomb excitation towards the first 2^+ state in ^{68}Ni was finished. The result is in agreement with the result obtained by intermediate energy Coulex performed at GANIL.

Beta decay studies on the neutron rich iron isotopes at LISOL, studying levels in cobalt, revealed the existence of an isomer at about 500 keV in ^{67}Co, the one-neutron hole neighbour of ^{68}Ni. This isomer can only be explained assuming a strong deformation for the ^{67}Co isotope indicating the swift onset of deformation, probably due to proton excitation through the Z=28 shell. A similar phenomena was observed in ^{66}Co that could not be described as a simple one-neutron hole, one-proton hole nucleus coupled to ^{68}Ni. Apart from this a wealth of data was obtained on the decay of ^{65}Co as well and a new measurement on the decay of ^{71}Co, ^{71}Ni, trying to identify an isomer in ^{71}Co that would feed the newly identified spin 1 /2 state. Analysis is still ongoing. In order to study the single particle nature of the states around ^{68}Ni, a new proposal to study the one-neutron transfer reaction on ^{66}Ni(d,p)^{67}Ni has been worked out and proposed to the CERN INTC committee. For this experiment a new reaction chamber was built in collaboration with T.U.München and the chamber was succesfully used in a one-neutron transfer reaction study of ^{30}Mg. The chamber is currently upgraded and the analysis of the data is underway.

A study of monopole shifts in various mass regions i.e. the detailed results on variations in the proton single-particle excitations for one neutron moving outside of the N=20, N=28, N=50 single-closed neutron shell nuclei or, for one proton moving outside of the Z=28, Z=50, Z=82 single-closed proton shell nuclei, has partly been finished. One of the major outcomes is that realistic forces (constructed starting from the CD potential of from the Kuo-Brown and Kuo-Herling interactions) give a rather good description of the major details. Another important result is the fact that purely central schematic forces are inconsistent with certain relative single-particle energy shifts and, two-body tensor forces are essential in order to remedy these shortcomings. A large paper is still in progress with as title "the changing mean-field in exotic nuclei: a shell-model point of view" but has got some delay because of the move of the major investigator, postdoctoral researcher N.Smirnova, to the University of Bordeaux.
Theoretical large-scale shell-model studies have been carried out for the odd-odd Cu nuclei as well as for the even-even Zn nuclei. In the latter nuclei, evidence for a closed N=50 shell, even for the very neutron-rich nuclei in this mass region shows up (see the joint papers in the publication list). The present calculations are near to the limits of the large-scale shell-model calculations because in the mass region which is treated using the fp shells mainly, unambiguous hints for the increasing importance of the $1g_{9/2}$ are showing up. Handling of the full $fp1g_{9/2}$ model space is at present beyond reach.

4.3
Coulomb excitation measurements on neutron deficient mercury beams has been performed at ISOLDE-CERN. Data on ^{184,186,188}Hg has been obtained. Excited states, in certain cases up to the 4^+ state, were observed. These data are currently under analysis and should allow us to determine the sign of the quadrupole deformation and the degree of mixing between the different shape coexisting bands in these neutron-deficient mercury isotopes. These experiments have to be complemented with new half life measurements for the excited states. An extension to study ^{182,180}Hg was prepared and approved and will take place in 2008. Laser spectroscopy measurements of the neutron-deficient polonium isotopes was performed succesfully down to mass ^{193}Po. Strong deviations from the spherical liquid drop model have been observed, furthermore, a change in the odd-even staggering of the mean square charge radii has been evidenced. Further analysis of the data is on going. The data are being compared to beyond mean field calculations from the Brussels group.

Detailed Interacting Boson Model (IBM - algebraic model) calculations have shed light on the microscopic shell-model truncation that is at the origin of multi-particle multi-hole excitations across closed shells (mp-nh) giving rise to collective bands in the very neutron-deficient mid-shell Pb nuclei. An extensive paper with the JYFL experimentalists group has recently been published as well as a study of charge radii in these Pb nuclei (see publication list). Recently, we have extended the approach in order to describe both energy spectra and B(E2) reduced transition probabilities for the Pb nuclei in the mass region ≤188 ≤196. Much care has been taken concerning the current classification that has been put up on the basis of level systematics. We suggest slightly different conclusion from our detailed IBM calculations and compare our results with the most recent experimental data in this mass region. The results of this study have recently been submitted for publication in Physical Review C.
A more general study of the criticality in mapping the full phase space diagram for shape coexistence has been thoroughly carried out. Phase diagrams with both analytical as well as numerical studies are constructed and compared. Indications for first-order and second-order shape phase transitions have been obtained starting from binding energies and from critical exponents, respectively. One paper has been published in Nuclear Physics A (part I) (see list of publications). A second one will be submitted soon, as part (II). In this paper, a careful study has been carried out such as to find out in parameter space where possibilities for reaching coexistence between prolate and oblate shapes might be possible.
A new approach to describe nuclear collective motion with the possibility of application to vibrational, rotational, gamma-soft and shape-coexisting phases, has been developed, using an algebraic approach based on a Cartan-Weyl basis. The matrix elements of the quadrupole collective variables, emerging from collective nuclear models are calculated in the natural Cartan-Weyl basis of O(5) which is a subgroup of a covering SU(1,1)xO(5) structure. Making use of an intermediate set method, explicit expressions of all matrix elements are obtained in a pure algebraic way, fixing the γ-rotational structure of collective quadrupole models. It is shown how a rotation from the mathematical basis to a physical basis carrying good angular momentum can be carried out in a fast and numerically stable way. First results have been obtained and the technique has been published as two papers in the J.Phys.A : Math.Phys. (see list of publications). This method will form the basis of a new research line that should enable to study general phase transitions as well as shape coexisting, for the coming years. An extensive collaboration with Prof.D.Rowe (Dept. of Physics, University of Toronto, Canada) and collaborators has been set up within the framework of the present IAP project.

The beyond mean-field method that has been previously developed has been successfully applied to several nuclei in the vicinity of the neutron deficient Pb isotopes. The first step of this method is constituted by mean-field calculations with a Skyrme effective interaction and a constraint on the axial quadrupole moment. These mean-field wave functions are then projected on good angular momentum and particle numbers. Configuration mixing as a function of the axial quadrupole moment is the last step of the method. In this way, one takes into account beyond mean-field correlations related to the rotational and vibrational motions of the nucleus.
An application to ^{188}Pb, ^{186}Pb and ^{194}Po has been first preformed in collaboration with a group of experimentalists from Jyväskylä and with the theory group of UGent. The determination of quadrupole transition probabilities and their comparison with the experimental data has enabled to analyse in details the large mixing of configuration that are obtained in these nuclei, in particular in Po which has a very soft dependence of energy as a function of the axial quadrupole deformation. The simultaneous application of our method and of the algebraic approach of the group from Gent has also permitted to confirm the importance of going beyond a single

configuration description of these nuclei. This work is actually complemented by a systematic application to neutron deficient nuclei from Pt (Z=78) to Rn (Z=86) which are actively studied experimentally, in particular by the group of the KULeuven.
An application of the same method to the determination of the isotopic shifts in Pb isotopes has also been performed in collaboration with the groups of Gent and of Leuven. Experimental results obtained at Isolde by the Leuven group have shown that the isotopic shifts obtained for the lightest Pb isotopes do not follow the trend that is predicted for spherical nuclei by the liquid drop model. Our results have shown the great sensitivity of the isotopic shifts to the mixing of different configurations in the ground states.

Finally, in the same mass region experimental evidence for beta delayed fission on ^{192,194}At has been observed from experiments at the SHIP velocity filter at GSI-Darmstadt. This exotic decay mode has now been firmly observed in the very neutron deficient nuclei around the closed Z=82 proton shell. Previous reports on beta-delayed fission of ^{180}Tl were never confirmed and showed an unexpected behaviour. Papers are in preparation and a new experiment especially focussed around ^{180}Tl is prepared at ISOLDE.

4.4
To investigate even heavier neutron-rich nuclei, more energetic primary beams are needed, such as provided by the GSI accelerators. At the FRS fragment separator, a campaign to measure g-factors of isomers around ^{132}Sn and in the Pb-region has been performed in the previous IAP phase, within the g-RISING collaboration (including our GSI and CSNSM partners). First results from this experimental campaign have been published, but the majority of physics result is now in the process of publication. Three new isomers have been observed in the ^{125,127,129}Sn isotopes, completing the isomer systematics approaching the N=82 shell gap. The g-factor of two isomeric states in ^{126}Sn and ^{127}Sn has been measured, supporting the tentatively assigned spin and configuration for these states. For the first time, spin-alignment has been observed in relativistic fission reactions, thus opening the way for isomeric moments studies on isotopes otherwise hard to orient. All these results will shed light on the evolution of shell structure when approaching the neutron-rich doubly-magic ^{132}Sn.

Objective 5:
We want to study the nuclei along the N=Z line elucidating the neutron-proton pairing interaction, verifying isospin symmetry and studying the weak interaction in the atomic nucleus.

	Workpackage 5: **Nuclei along the N=Z line**	**Partners**
1	Mass measurements of N=Z nuclei	K.U.Leuven - GSI
2	Theoretical studies along the N=Z line	U.Gent – U.L.B. - GANIL
3	Beta-decay studies along the N=Z line	K.U.Leuven – GSI
4	Improve the efficiency and sensitivity of the WITCH set-up	K.U.Leuven – GANIL - GSI
5.	Optimise the determination of the beta-asymmetry parameter and obtain improved precision	K.U.Leuven – CSNSM
6	Weak interaction studies using the WITCH spectrometer and low-temperature nuclear orientation devices	K.U.Leuven – GANIL - CSNSM

5.1
No activity to be reported

5.2 (also in 4.1)
A major improvement of the method that we have developed has been finalised in 2007: the simultaneous treatment of axial and non axial quadrupole deformations and the breaking of time reversal invariance. Both developments should significantly improve our description of spectra and in particular correct for the overestimation of excitation energies that are obtained in deformed nuclei. The price to be paid is an increase of the computing times by at least an order of magnitude and a significant complication of the codes. However, this new tool is unique and should open an enormous range of new applications: odd nuclei, new excitation modes of even nuclei, improvement of the correlations that are taken into account for a systematic description of masses, etc. A test application to ^{24}Mg shows that the triaxial degree of freedom has indeed a significant effect on excitation energies. The method is satisfactorily working, but still requires further improvements to be systematically applicable to medium mass nuclei. First applications to nuclei in the neutron rich N=20 and N=28 region should be performed in the next two years.

We have carried out a quantum Monte-Carlo method to solve a general isovector pairing model, in which both angular momentum and parity projections could be carried out without introducing a sign problem. This technique allows us to calculate angular momentum plus parity projected level densities (Jπ densities) in atomic nuclei. We have carried out these calculations for Fe isotopes with both odd (mass A=55 and 57) and even (A=56) number of nucleons using the full sd+fp+1$g_{9/2}$ +sd shell-model space. Signatures of the pairing phase transition are observed in the angular momentum distribution of the nuclear level densities. It is moreover shown that one needs to use indeed the largest possible model spaces in order to reach converged results. The results are available in preprint form and are also in press for Phys.Rev.C.

5.3
The new laser ion source developed for the LISOL separator whereby the shadow method is used to reduce the unwanted isobaric contamination allows us to further explore the N=Z line using heavy ion fusion evaporation reactions. A pre-study to investigate the feasibility of the new experiments has been initiated taking into account the new efficiency and selectivity obtained off-line.

5.4
The beam transport efficiency of the WITCH set-up was further improved. Over the last three years a gain of about a factor 100 was realized. Also, ion clouds of 104 to 105 ions can now be kept for up to several seconds in the Penning traps, without significant losses. Further, new Penning traps were installed providing a mass resolution of about 200.000. Analysis of the first measurement of a recoil ion energy spectrum with trapped 124In has yielded the first physics results with WITCH, i.e. the charge state distribution of the 124Sn recoil ions.
Several technical improvements have been worked on or are being prepared:
- installation of a magnetic shield to create more possibilities for testing with stable beams (now limited due to the stray field of the WITCH magnet which disturbs the beam transport in the neighbouring REX-ISOLDE beamline);
- installation of an ion source;
- simulations and measurements to better understand the creation of secondary ions in the set-up.

5.5

Last year already a precision of 2% on the asymmetry parameter for ^{60}Co was obtained, i.e. as good as the best result available in literature to date. In the mean time the amount of statistics in the Geant 4 Monte Carlo simulations that are used in the data analysis was improved by a factor of 10. These results are at present being analyzed. A new measurement was in the mean time performed as well, using ^{67}Cu at ISOLDE-CERN. Also these data are still being analyzed.

5.6
This can only start when the respective experimental devices will be fully optimised. No activity to be reported.

Objective 6:
We want to study neutron-induced reactions on rare isotopes of interest for astrophysical and nuclear waste transmutation processes.

	Workpackage 6: **Structure and reactivity of rare actinides**	**Partners**
1	Structure and reactivity of rare actinides, experimental determination of the Cm(n,f) cross section	SCK•CEN, U.Gent, U.L.B., CSNSM

6.1
The thermal neutron induced fission cross section of a series of Cm isotopes needs to be determined at the BR1 reactor at SCK•CEN. For this purpose a dedicated experimental setup was installed at one of the irradiation channels of BR1:

- A first series of measurements will be performed using a twin Frisch-gridded gas flow ionisation chamber. This chamber was developed in collaboration with partner U.Gent. A special detector holder was constructed such that the detector can be positioned in the beam line about 0.5 m from the reactor wall. This holder is connected to the reactor to assure a stable positioning of the detector at all time.
- An efficient neutron and gamma shielding was constructed around the detector such that human presence near the setup is possible without being exposed to high radiation doses.
- The BR1 reactor channel is cylindrical with a section of 8 cm. The neutron beam at the sample position should have a section between 15 mm and 40 mm. Therefore a collimator had to be installed. A first collimation is done via a 1.4 m long concrete collimator in the reactor channel, having partly an inner diameter of 6 cm and partly of 7 cm. Three smaller collimators are inserted in this long collimator: an iron collimator of length 21 cm and inner diameter 4.15 cm at the 'reactor side' and two B4C collimators of length 10 cm and inner diameter 1.55 cm, one in the middle and one at the "detector side". Finally a boron sleeve with a hole of 1.5 cm is attached to the ionisation chamber which serves as a final collimation to stop scattered neutrons.

The final alignment of the ionisation chamber to the neutron beam axis was done using a mobile neutronography installation. This device consists of a gadolinium neutron converter and a photographic film. These photgraphic films were afterwards analysed with a densitometer to investigate the homogeneity of the beam profile, which confirmed that the neutron beam is homogeneous over the active target area of 1.5 cm.

The acquisition system was developed by U.Gent and modified to the specific requirements of the experiments at BR1. The electronics are also partly provided by U.Gent. The entire system has been installed at the BR1 reactor and first test measurements were performed using inactive boron and lithium samples.

A crucial step in the experimental procedure is the characterisation and absolute calibration of the neutron flux at the sample position. For this purpose thin gold foils were irradiated at the sample position, with and without a cadmium thermal neutron shield. The activity of these irradiated gold foils was determined at the reactor dosimetry laboratory of SCK•CEN with an uncertainty of less than 2 %. From these measurements it was deduced that the thermal to epithermal flux ratio is about 60. Epithermal neutrons will also induce fission reactions in the Cm that will have to be corrected for, thus the higher the thermal to epithermal flux ratio, the better. Therefore it was decided to insert extra moderating material (graphite) in the centre of the reactor channel before the start of the actual Cm(n,f) measurements. This is currently being discussed with the reactor exploitation team.

A ^{245}Cm sample has been ordered in Russia and has been delivered end of November 2007. The collimation of neutron flight path 17 at the GELINA neutron time of flight facility of the Institute for Reference Materials and Measurements (IRMM) in Geel has been adapted for this measurement. A vacuum chamber with two 3000 mm^2 silicon surface barrier detectors for the detection of ^{245}Cm(n,fission) fragments and ^{10}B(n,α) particles (for the determination of the neutron flux) has been prepared and has been mounted at this beam position. The preparation and testing of the electronic chains needed for the data acquisition has been started.

On the theoretical side we investigate the predictive power of our method and the range of validity of the present effective nucleon-nucleon interactions. To do so we have continued our systematic studies of quasi-particle excitations in nuclei around the No isotopes (Z=102). There is indeed an intense experimental activity in this mass region and these excitations are very sensitive to the single-particle properties predicted by mean-field methods. A very satisfactory agreement is obtained for most odd nuclei in this mass region (one quasi-particle excitations). On the contrary, there are strong discrepancies obtained by our calculations but also by calculations based on other families of effective interactions for isomeric states based on two-quasi-particle excitations in even nuclei. The origin of this discrepancy is still unclear and requires further analyses of the interaction and the way we describe 2-qp states. We hope that these analyses will permit to improve the predictive power of our method not only for very heavy nuclei but also in other regions of the nuclear chart.

Objective 7:
We want to investigate the feasibility of using the high power proton beam that will become available in the MYRRHA accelerator driven system for Belgian fundamental nuclear-physics research.

	Workpackage 7: **Physics with intense proton beams**	**Partners**
1	Feasibility/exploratory study of an irradiation station with 5/2.5 mA protons at 350/600 MeV, opportunities for Belgian fundamental research on radioactive nuclei on the long term	SCK•CEN, K.U.Leuven, U.Gent, U.L.B. - Köln

7.1
The development of the MYRRHA accelerator driven system that serves as a basis for the European experimental XT-ADS is one of the important activities of SCK•CEN. In this workpackage we want to investigate the feasibility of using the high power proton beam that will become available in the MYRRHA accelerator driven system for fundamental research.

In order to have a global overview of existing large-scale proton facilities and research programmes, it was decided to organise a workshop on these topics. This two-days workshop will be hosted by SCK•CEN and is organised in close collaboration with K.U.Leuven. The workshop will take place in April 2008. The programme was worked out in 2007 and is organised as follows:

- In the first session, technical information and the capabilities of some of the most important large scale proton facilities will be presented. At the end of this session, the MYRRHA machine will be introduced, with a focus on the accelerator and the spallation target.
- In the second session a broad overview of research programmes at existing facilities (including nuclear physics, fundamental interaction studies using beta decay, physics with atomic traps, solid state physics using short lived radioactive nuclei,...) will be given.
The session will start with a presentation on the possibility for an ISOL facility at MYRRHA and the beams that might become available with MYRRHA and their properties. The ISOL facility plans to focus on a limited number of ruggedized target-ion source systems that produce intense beams of alkali and gaseous elements. This limitation is compensated by very long beam times that will be available for high-precision experiments, experiments hunting for extremely weak signals or experiments with an inherently low efficiency. The speakers will give their view on possible applications at the MYRRHA facility within their research domain, focussing on the type of measurements mentioned above requiring long beam times and intense radioactive beams.
- The third session will start with an overview of the MYRRHA facility in a broader European context followed by a general discussion and round-up of the workshop.

All details on the workshop can be found on the website at following address: http://www.sckcen.be/sckcen_en/activities/conf/conferences/brix/index.shtml.

2. Network organisation and operation

After a voting procedure and in order to increase the visibility of the IAP network a name and acronym was proposed: **"Belgian Research Initiative on eXotic nuclei: BriX"**.

The network involves experimental nuclear physics groups from the universities of Leuven (K.U.Leuven) and Gent (U.Gent) and theoretical groups from the universities of Brussels (U.L.B.) together with the European partners GANIL (France), GSI (Germany), IKP – U.Köln (Köln) and CSNSM (Orsay). An intense collaboration with ISOLDE-CERN (Switzerland) exists as well. During the numerous experimental campaigns at ISOLDE-CERN, GANIL, GSI and at the Orsay tandem accelerator contacts between the different members of the BriX network are established. A "wiki type" webpage has been created allowing all members of the network to be involved in the construction and maintenance of the web page:
http://iks32.fys.kuleuven.be/iap_wiki/index.php/Main_Page

Apart from the research performed within the groups, an intense networking activity is developed that results in a number of joint publications (see list of "co-publications"). Partners of the network are also involved in the organization of different workshops and schools.

a. Meetings and worskhops

Apart from the seminars and specific discussion meetings between the different partners, a few workshops and schools were organized (partly) in the framework of the IAP network. These workshops and schools are listed below:

"IAP - BriX day"
January 23, 2007, Leuven, Belgium

"Euroschool on Exotic Beams"
August 26 – 31, 2007, Houlgate, France

"Seminar on Fission VI"
Corsendonk Priory, Belgium, 18-21 September 2007

"Exploratory visit: opportunities for Flemish nuclear physics research at the ILL"
Institut Laue-Langevin, Grenoble, 22-23 October 2007

"Nuclear Many-Body approximations for the 21st century"
INT, Seattle, from September 24 until November 30,2007

"ISOLDE Workshop and Users Meeting"
December 17 - 19, 2007, CERN, Geneva, Switzerland

b. Exchange of data, material and personnel

Exchanges of personnel within the IAP

- S. Rombouts 1.9.2007: associate professor at University of Aarhus
- S. De Baerdemacker 1.11.2007: long stay at the Physics deparment of the University of Toronto, Canada (group of prof. D.Rowe) within the IAP
- V. Hellemans: 1.1.2008: postdoc at the ULB, Brussels (group of prof.P.-H.Heenen) within the IAP

- N. Smirnova: 1.9.2006: left the former IAP P5/07 network to take up a permanent position as 'Maitre de Conférences' at the 'Université de Bordeaux'
- K. Van Houcke: 1.10.2007: postdoct at the FWO with a 1 year stay at the Physics department of the University of Amherst, USA.
- N. Vermeulen, Ph.D. student at K.U. Leuven and graduating mid 2008, will start as a post-doctoral researcher at GANIL.
- R. Raabe, Post-Doc at K.U.Leuven obtained a permanent position (CEA) at GANIL.
- D. Yordanov, PhD student at K.U.Leuven obtained a post-doc position at ISOLDE
- B. Bastin, PhD student at LPC-GANIL-Caen obtained a post-doc position at K.U.Leuven
- Staff from the ULB (S. Goriely and P.H. Heenen) and of U.Gent (K. Heyde) is teaching specialized nuclear physics and astrophysics courses in the 'Master of physics' trajectory of "physics on femtometer scale: nuclear physics" at the K.U. Leuven.

Exchange of data and material

The doctoral thesis research of G. Ilie at U. Koln under supervision of J.Jolie, is partly based on an experiment proposed by the Leuven group (G. Neyens) at GSI. Several meetings between the Leuven-Koln teams have taken place in 2007, to discuss the progress of the analysis and publication of results.

An experimental set-up to perform b-NMR experiments has been moved from Leuven to GANIL for an experiment to measure ground state g-factors of Cl isotopes in December 2007.

Exchange of material between SCK•CEN and U.Gent for workpackage 6. Acquisition system, ionisation chamber and part of the electronics are provided by U.Gent for the measurements at the BR1 reactor. Training of L. Popescu (SCK•CEN) on the acquisition system by U.Gent.

Establishment of the programme of the workshop that is being organised in the frame of Workpackage 7 in close collaboration with K.U.Leuven. This workshop will be followed by a BriX network meeting.

Exchange of data on the Cu Coulex between K.U.Leuven and CSNSM has been established.

Exchange of data on the Po laser spectroscopy between K.U.Leuven and ISOLDE has been established.

3. List of publications

a. List of publications for every partner

K.U.Leuven

Physical Review Letters 98 (2007) 072501
"No evidence for oblate shape in 70Se: Measurement of the sign of the spectroscopic quadrupole moment for the 2+ state"
A. M. Hurst, P. A. Butler, D. G. Jenkins, P. Delahaye, F. Wenander, F. Ames, C. J. Barton, T. Behrens, A. Baurger, J. Cederkall, E. Clement, T. Czosnyka, T. Davinson, G. de Angelis, J. Eberth, A. Ekstrom, S. Franchoo, G. Georgiev, A. Gorgen, R.-D. Herzberg, M. Huyse, O. Ivanov, J. Iwanicki, G. D. Jones, P. Kent, U. Koster, T. Kroll, R. Krucken,4 A. C. Larsen, M. Nespolo, M. Pantea, E. S. Paul, M. Petri, H. Scheit, T. Sieber, S. Siem, J. F. Smith, A. Steer, I. Stefanescu, N. U. H. Syed, J. Van de Walle, P. Van Duppen, R. Wadsworth, N. Warr, D. Weisshaar and M. Zielinska

Physical Review Letters 98 (2007) 112502
"Nuclear charge radii of neutron deficient lead isotopes beyond N=104 mid shell"
H. De Witte, A. N. Andreyev, N. Barre, M. Bender, T. E. Cocolios, S. Dean, D. Fedorov, V. N. Fedoseyev, L. M. Fraile, S. Franchoo, V. Hellemans, P. H. Heenen, K. Heyde, G. Huber, M. Huyse, H. Jeppessen, U. Koster, P. Kunz, S. R. Lesher, B. A. Marsh, I. Mukha, B. Roussiere, J. Sauvage, M. Seliverstov, I. Stefanescu, E. Tengborn, K. Van de Vel, J. Van de Walle, P. Van Duppen, and Yu. Volkov

Physical Review Letters 98, (2007) 122701
"Coulomb excitation of ^{68,70}Cu; first use of post-accelerated isomeric beams"
I. Stefanescu, G. Georgiev, F. Ames, J. Aysto, D. L. Balabanski, G. Bollen, P. A. Butler, J. Cederkall, N. Champault, T. Davinson, A. De Maesschalck, P. Delahaye, J. Eberth, D Fedorov, V. N. Fedosseev, L. M. Fraile, S. Franchoo, K. Gladnishki, D. Habs, K. Heyde, M. Huyse, O. Ivanov, J. Iwanicki, J. Jolie, B. Jonson, Th. Kroll, R. Krucken, O. Kester,U. Koster, A. Lagoyannis, L. Liljeby, G. Lo Bianco, B. A. Marsh, O. Niedermaier, T. Nilsson, M. Oinonen, G. Pascovici, P. Reiter, A. Saltarelli, H. Scheit, D. Schwalm, T. Sieber, N. Smirnova, J. Van DeWalle, P. Van Duppen, S. Zemlyanoi, N.Warr, D.Weisshaar, and F.Wenander

Physical Review Letters 98 (2007) 172501
"Sub-barrier Coulomb Excitation of ^{110}Sn and its Implications for the ^{100}Sn Shell-closure"
J. Cederkall, A. Ekstrom, C. Fahlander, A. M. Hurst, M. Hjorth-Jensen, F. Ames, A. Banu, P. A. Butler, T. Davinson, U. Datta Pramanik, J. Eberth, S. Franchoo, G. Georgiev, M. Gorska, D. Habs, M. Huyse, O. Ivanov, J. Iwanicki, O. Kester, U. Koster, B. A. Marsh, O. Niedermaier, T. Nilsson, P. Reiter, H. Scheit, D. Schwalm, T. Sieber, G. Sletten, I. Stefanescu, J. Van de Walle, F. Wenander, P. Van Duppen, N. Warr, and D. Weisshaar

Physical Review Letters 99 (2007) 142501
"Coulomb Excitation of Neutron-Rich Zn Isotopes: First Observation of the 2^+ State in ^{80}Zn"
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